# Environmental Effects of Energy Production, Transformation and Consumption in the National Capital Region

Interim Report Submitted to

The Ministry of Environment and Forests

By

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## 1. SCOPE OF THE INTERIM REPORT

The objectives of the project "Environmental Effects of Energy Production, Transformation and Consumption in the National Capital Region (NCR)" sponsored by the Department of Environment and Forests in May, 1989 are the following:

1. To develop a methodology for assessing the effects of energy production, conversion, distribution in different sectors of the economy on the environment in the NCR.
2. To establish quantitative relationships between the type and extent of an energy activity and the concentrations of pollutants in air through the estimation of emission factors. To develop framework whereby models could be developed of other regions of the country.
3. To quantify environment not only on a regional basis but also to determine locations in the region more vulnerable to pollution.
4. To develop scenarios of future trends in energy related activities and with the help of models developed arrive at desirable and acceptable levels of pollution control.

The major activities in this study comprise of

1. Understanding the energy related activities in the various sectors of economy in the National Capital Region.
2. Compiling a data base for NCR regarding energy and environmental parameters.
3. Developing a suitable mathematical model to predict the environmental impacts of energy systems in the NCR.

4. Generating future scenarios of environmental impacts based on alternatives in the energy systems.

In this interim report, we have presented the details of various energy sectors in the National Capital Region. In addition, demographic and settlement patterns are described. We propose to develop a linear dispersion model to capture the environmental impacts of energy production and use. The data on emission factors of the five criteria pollutants from different processes is compiled. The information gathered so far on vehicular traffic and other energy related parameters is presented. Finally, a work plan for the remaining period of project is prepared.

## 2.0 NATIONAL CAPITAL REGION

### 2.1 INTRODUCTION

The National Capital Region was delineated for the purpose of developing a region around the Union Territory of Delhi in a balanced and harmonious manner. The prime purpose is to substantially reduce the inflow of migrants into Delhi over years such that the population of Delhi UT is contained to 112 lakhs by 2001 AD. This region spreads with the Delhi UT as its core, over parts of the states of Haryana, Rajasthan and Uttar Pradesh.

#### 2.1.1 Constituents of the NCR

The administrative units and their extent are as under:

(i) Union Territory of Delhi (1483 sq.km)

(ii) Haryana subregion (13,413 sq.km) comprising of Faridabad, Gurgaon, Rohtak and Sonepat districts; Rewari and several tehsils of Mahendragarh district and Panipat tehsil of Karnal district. This accounts for 30.33% of the area of the state.

(iii) Rajasthan subregion (4,493 sq.km) comprising six tehsils of Alwar district namely Alwar, Ranzgahr, Behroor, Mandwar, Kishangarh and Tijara. The area under the region is 1.31% of the total area of the state.

(iv) Uttar Pradesh subregion (10,853 sq.km) comprising 3 districts namely Meerut, Ghaziabad and Bulandshahr. About 3.68% of the area of Uttar Pradesh is under the region (Fig. 1).

**Table 1 .: Area and Population of the NCR**

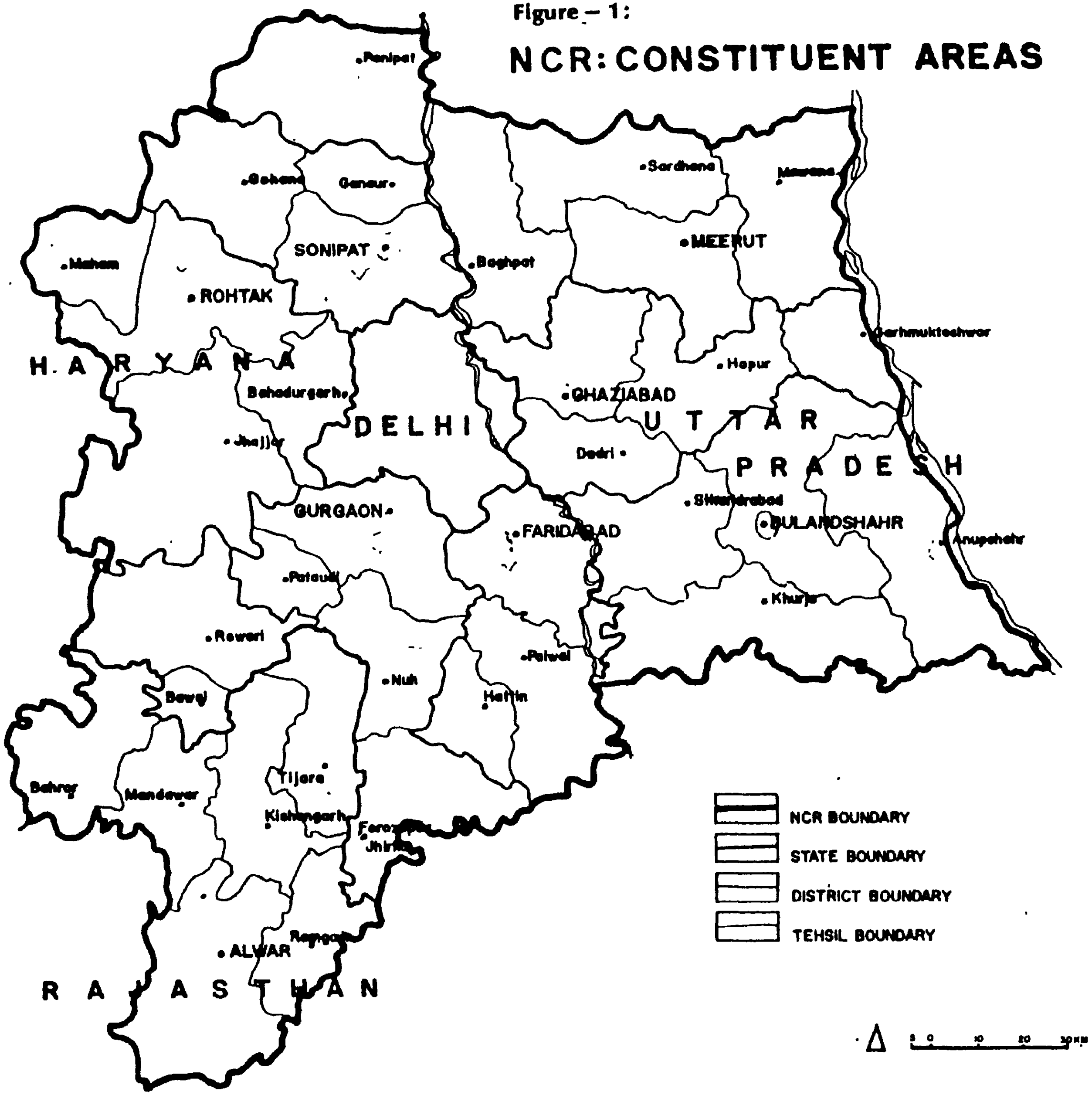
(Population in lakhs)

| Sub-region | Area sq.km 1981 | Population 1961 | Population 1971 | Population 1981 | Growth rate % 1971-81 |
|---|---|---|---|---|---|
| Delhi UT | 1483<br>(4.90) | 26.6<br>(25.11) | 40.6<br>(28.91) | 62.2<br>(32.41) | 53.2 |
| Haryana | 13413<br>(44.36) | 28.9<br>(27.33) | 38.0<br>(27.01) | 49.4<br>(25.74) | 30.0 |
| Rajasthan | 4493<br>(14.86) | 5.8<br>(5.52) | 7.6<br>(5.39) | 10.6<br>(5.54) | 39.47 |
| Uttar Pradesh | 10853<br>(35.88) | 44.5<br>(42.04) | 54.4<br>(38.69) | 69.7<br>(36.31) | 28.12 |
| N C R | 30242<br>(100.00) | 105.8<br>(100.00) | 140.6<br>(100.00) | 191.9<br>(100.00) | 36.48 |

Note: Figures in brackets indicate proportions(%) to NCR total

Figure - 1:

NCR: CONSTITUENT AREAS



### 2.1.2 Objectives of NCR

The regional population is projected to remain at 325 lakhs of which 234 lakhs will be urban and 91 lakhs rural by the year 2001. The main objective of the regional plan is to restrict the share of Delhi subregion to 112 lakhs as against the projected 132 lakhs. While restricting the growth of Delhi, it is necessary to ensure that the differences in the growth is controlled within the region in a planned manner. It is also necessary that the resultant extra growth in the region outside Delhi is of such a nature that it will have an overall effect in the entire region, stimulating its regulated and orderly growth in and around the centres selected for development.

## 2.2. DEMOGRAPHIC AND SETTLEMENT PATTERN

### 2.2.1 Population distribution of NCR

The National Capital Region accomodated a total population of 191.92 lakhs in 1981. Of this Uttar Pradesh subregion accounted for a major share of 36.31% followed by Delhi UT (32.41), Haryana (25.74) and Rajasthan (5.54%) (Table 1). However, Delhi has been adding population unabatedly and is emerging fast as a major population absorbant among the NCR constituents, having increased its contribution from 25.11% in 1961 to 32.41% in 1981 to the population of the NCR.

2.2.1.1 **Urban Population:** Over 91 lakhs or 47.4% of the population in the region resided in urban areas in 1981 as against only 39.28% in 1971. The fact that the NCR is getting fast urbanised is evident from the declining rural population proportion from 65.31% in 1961 to 60.72 in 1971 and 52.6% in 1981 (Table 2).

**2.2.1.2 Density 1981:** The density of population in the NCR was 634 per 1 sq.km against the all India average of 221 in 1981. Of the constituents of the region, Delhi is the most conjested with 4292 persons over one sq.km area followed but distantly by the Uttar Pradesh subregion with 642. The other two subregions are significantly below the regional average (Table 3).

**Table 3: Density Pattern**

| Density Area | Density |
|---|---|
| Union Territory of Delhi | 4192 |
| Haryana | 368 |
| Rajasthan | 238 |
| Uttar Pradesh | 642 |
| NCR | 634 |
| Indian | 221 |

### 2.2.2 Settlement System

**2.2.2.1 Rural:** There are 6677 villages (1981) in NCR. Villages are predominently medium sized with 55% of them having population 500-1999 persons and 20.75% of them 2000-4999 persons (Table 2).

**2.2.2.2 Urban:** There are 94 urban centres in the NCR with 6 in the Union Territory of Delhi, 58 in Uttar Pradesh, 27 in Haryana and 3 in Rajasthan subregion.

There are 11 class I urban centres including Delhi accommodating about 70% of the urban population of the NCR. As such, as much as 63.45% of the entire urban population of the NCR is concentrated in Delhi alone. Of the remaining 21.44% is in Uttar Pradesh followed by 13.19% in Haryana and 1.92% in Rajasthan subregion classwise proportions of urban population in Class I to IV urban centres are 10.32% , 1.38%, 4.55%, 3.15%, 2.3% and 0.10% respectively Table 4.

**2.2.2.3 Major Urban Structures:** The first order priority settlements (for accelerating growth) in the participating states (Table 5) (Fig.2) are:

1. Uttar Pradesh Sub-region: Meerut, Hapur and Bulandshahr
2. Haryana subregion: Panipat, Rohtak, Rewari, Dharuhera & Palwal
3. Rajasthan sub-region: Alwar and Bhiwadi

**Table 5: Population for priority towns**

| Priority town | Actual population 1981 (lakhs) |
|---|---|
| Meerut | 5.36 |
| Hapur | 1.02 |
| Bulandshahr | 1.03 |
| Khurfa | 0.67 |
| Palwal | 0.47 |
| Panipat | 1.38 |
| Rohtak | 1.68 |
| Rewari | |
| Dharuhera | 0.52 |
| Bhiwadi | |
| Alwar | 1.47 |
| Total | 13.60 |

### Table . 2 . Number of Villages in Different Population Range – 1981

| Sub-region | No. of Villages | Population Less than 200 | 200–499 | 500-1999 | 2000–4999 | 5000–9999 | 10000 and above |
|---|---|---|---|---|---|---|---|
| Delhi U.T. | 214 | 9<br>(4.20) | 9<br>(4.20) | 110<br>(51.40) | 71<br>(33.20) | 15<br>(7.00) | – |
| Haryana | 2386 | 158<br>(6.62) | 335<br>(14.04) | 1287<br>(53.94) | 508<br>(21.29) | 93<br>3.90) | 5<br>(0.21) |
| Rajasthan | 1088 | 125<br>(11.49) | 318<br>(29.23) | 573<br>&52.67) | 65<br>(5.97) | 7<br>(0.64) | –<br>– |
| U.P. | 2989 | 149<br>(4.98) | 283<br>(9.47) | 1705<br>(57.04) | 742<br>(24.83) | 107<br>(3.58) | 3<br>(0.10) |
| N.C.R. | 6677 | 441<br>(6.60) | 945<br>(14.10) | 3675<br>(55.10) | 1386<br>(20.75) | 222<br>(3.32) | 8<br>(0.13) |

Note: Figures in brackets indicate proportions to respective sub-region's total

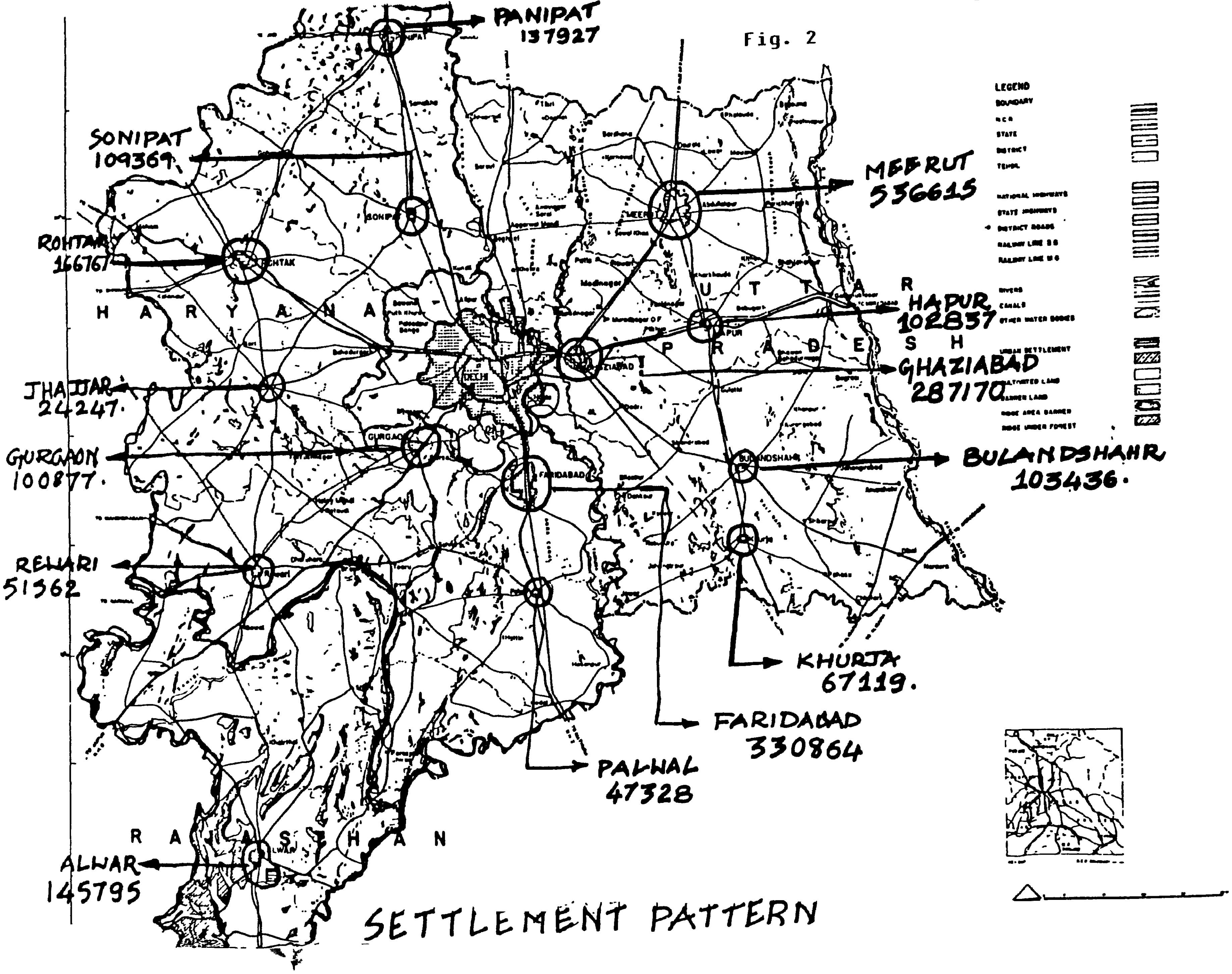
### Table 4 Distribution of Urban Settlements 1961-81

| Size Class | N.C.R. 1961 | N.C.R. 1971 | N.C.R. 1981 | Delhi UT 1981 | UP-Sub Region 1981 | Haryana Sub-Region 1981 | Rajasthan Sub-Region 1981 |
|---|---|---|---|---|---|---|---|
| I. | 2 | 4 | 11 | 1 | 4 | 5 | 1 |
| II. | 3 | 6 | 3 | – | 2 | 1 | – |
| III. | 10 | 9 | 16 | – | 12 | 4 | – |
| IV. | 12 | 13 | 28 | 1 | 17 | 8 | 2 |
| V. | 13 | 14 | 33 | 4 | 20 | 9 | – |
| VI. | 4 | 2 | 3 | – | 3 | – | – |
| All Classes | 44 | 48 | 94 | 6 | 58 | 27 | 3 |

Note: Figures indicate number of urban centres.

# LAND USE 1986-87

Fig. 2



SETTLEMENT PATTERN

### 2.2.3 Regional Landuse

1) The entire NCR except in Aravalli ridge in the South-West, is a fertile flat plain.

2) The landuse analysis of the region reveals that agriculture is the predominant user of land. Table 6 shows subregionwise landuse distribution.

3) The cultivated area constitutes about 80% of the total reporting area. Of the region's total cultivated area, about 46% is concentrated in the Haryana subregion followed by the up subregion (37.3%) while Delhi UT has the least (3.7%).

4) The land put to non agricultural use which comprise area under settlements, transport network, rivers and canals covers 9.9% of the total area. The Haryana subregion has the highest area of 128431 (38.7%) and the Delhi UT (12.1%).

5) Barren land which includes rocky areas, saline patches, gullied land, derelict land and covers an area of 141677 hectares or 4.7% of the total area of region. The highest concentration is in Rajasthan subregion (39.8%) followed by the Haryana sub-region (24.7%). The UP subregion (22.3%) and lastly Delhi UT (13.2%).

6) According to land records forest covers a total area of 65222 hectares which forms 2.1% of the total area of the region and shows highest concentration in Haryana subregion (52.3%) followed by UP subregion (30.5%) and Rajasthan subregion (15.2).

7) According to the forest departments of the NCR states, the total area under forest is 153474 hectares with a break up as shown in Table 7.

8) The categorywise distribution of forest area (Table 6) reveals that out of the total forest area about 51% is concentrated in the Rajasthan subregion followed by the Haryana subregion (28.5%) and UP subregion (19.4%).

## 2.3 INDUSTRY

The NCR is endowed with some of the best industrially developed areas of the constituent states, and this sector is a major source of pollution of atmosphere.

### 2.3.1 Industry (Existing pattern)

**Haryana Subregion**

A major portion of industrial activities in Haryana state is located in the Haryana subregion. Out of the total number of registered factories in the Haryana state, 58.97% are located in the districts of the Haryana subregion (Table 8).

The distribution of registered units and their employment for the year 1983 amongst the districts of subregion shows that regional concentration is a major characteristic of the industrial units and employment in Faridabad, Karnal and Sonepat disticts. These districts comprised 44.9%, 24.38% and 10.33% of registered factories.

**Table 6 Landuse in the NCR–1986-87 (Sub-regionwise Distribution)**

(Area in Hectares)

| Category | Delhi | Haryana | Rajasthan | Uttar Pradesh | NCR | Proportion reported |
|---|---|---|---|---|---|---|
| 1. Forest | 1434<br>(2.2) | 34000<br>(52.1) | 9870<br>(15.2) | 19918<br>(30.5) | 65222<br>(100.00) | 2.1 |
| 2. Land put to non-agricultural use | 35820<br>(24.2) | 128431<br>(43.3) | 17398<br>(5.9) | 114860<br>(38.7) | 296509<br>(100.00) | 9.9 |
| 3. Barren Land | 18707<br>(13.2) | 35000<br>(24.7) | 56425<br>(39.8) | 31545<br>(22.3) | 141677<br>(100.00) | 4.7 |
| 4. Water Bodies | 329<br>(4.0) | 3569<br>(42.9) | 2407<br>(28.9) | 2017<br>(24.2) | 8323<br>(100.00) | 0.28 |
| 5. Permanent pasture & Other grazing land | 793<br>(3.0) | 12000<br>(45.0) | 11262<br>(42.3) | 2593<br>(9.7) | 26648<br>(100.00) | 1.2 |
| 6. Land Under Misc tree crops and groves | 1137<br>(24.0) | – | 91<br>(1.9) | 3512<br>(74.1) | 4740<br>(100.00) | 0.2 |
| 7. Culturable Waste | 856<br>(1.5) | 24000<br>(41.8) | 7073<br>(12.2) | 25555<br>(44.5) | 57484<br>(100.00) | 1.8 |
| 8. Cultivated Land | 88411<br>(3.7) | 1099000<br>(45.9) | 314419<br>(13.1) | 890288<br>(37.3) | 2392118<br>(100.0) | 79.9 |
| Total Reporting Area | 147487<br>(4.93) | 1336000<br>(44.64) | 418945<br>(14.00) | 1090288<br>(36.43) | 2992720<br>(100.00) | 100 |

Figures in brackets indicate percentages to total of the NCR
Sources: Compiled from State Government records.

**Table 7 Distribution of Forest Area in NCR-1985**

| Sub-region | Total Reporting area | Total forest | Reserved forest | Protected forest | Unclasified forest | Social forest |
|---|---|---|---|---|---|---|
| Delhi UT | 149788 | 1443<br>(0.9) | NA | NA | NA | NA |
| Uttar Pradesh | 1075993 | 29455<br>(19.4) | 16308<br>(29.4) | 1995<br>(6.3) | 1064<br>(1.9) | 10088<br>(100.0) |
| Haryana | 1334640 | 43815<br>(28.5) | 7346<br>(13.2) | 20850<br>(65.9) | 15619<br>(27.8) | NA |
| Rajasthan | 420348 | 78761<br>(51.3) | 30447<br>(54.8) | 8795<br>(27.8) | 39519<br>(70.3) | NA |
| NCR | 2980769 | 153474 | 55544 | 31640 | 56202 | 10088 |

*Source:* State Forest Departments & Delhi Administration
*Note:* Figures in brackets indicate percentages to total of the respective category of forest.

Table 8 Registered Factories in Haryana Sub-region — 1983

| District | No. of registered factories(%) | No. of working factories | No. of workers (%) |
|---|---|---|---|
| 1. Gurgaon | 210 (7.87) | 175 | 9844(6.17) |
| 2. Faridabad | 1197 (44.90) | 1146 | 105435 (66.06) |
| 3. Mohindergarh | 106 (3.97) | 99 | 4016 (2.52) |
| 4. Karnal | 650 (24.38) | 613 | 16464 (10.32) |
| 5. Sonepat | 275 (10.33) | 263 | 13900 (8.71) |
| 6. Rohtak | 228 (8.55) | 215 | 9949 (6.22) |
| Sub-region | 2666 (100.0) | 2511 | 159608 (100.0) |
| Haryana State | 4522 | | 232404 |
| Sub-region as % of state. | 58.97 | | 68.68 |

Source: Statistical Abstract of Haryana — 1983-84.

### Table 9 District-wise concentration of registered factories in U.P. Sub-Region

| District | No. of Registered Factories in | | | |
|---|---|---|---|---|
| | 1978-79<br>(%) | 1979-80<br>(%) | 1980-81<br>(%) | 1983-84<br>(%) |
| Meerut | 276<br>(28.25) | 270<br>(28.51) | 284<br>(30.47) | 401<br>(29.68) |
| Bulandshahr | 104<br>(10.64) | 98<br>(10.35) | 93<br>(9.98) | 138<br>(10.21) |
| Ghaziabad | 597<br>(61.11) | 599<br>(61.14) | 555<br>(59.55) | 812<br>(60.11) |
| Total | 977 | 947 | 932 | 1351 |

**Source:** District Statistical Hand books : 1986.

### Table 10 Distribution of Registered Factories (Industries-wise) in Alwar district – 1983.

| SL No. | N.I.C. Code | Type of Industry | Units (%) | Employment (%) |
|---|---|---|---|---|
| 1. | 204.1 | Atta Mill | 1<br>(0.36) | 15<br>(0.19) |
| 2. | 204.9 | Dal Mill | 9<br>(3.23) | 70<br>(0.86) |
| 3. | 211 | Mfg. of edible oil and fats | 47<br>(16.85) | 95<br>(1.17) |
| 4. | 23 & 24 | Mnfg. of textiles | 10<br>(3.58) | 2500<br>(30.84) |
| 5. | 271 | Sawing and planning of wood | 24<br>(8.60) | 60<br>(0.74) |
| 6. | 289 | Printing, publishing and allied activities | 44<br>(15.77) | 160<br>(1.97) |
| 7. | 312 | Mnfg. of paints, varnishes and lacquers | 2<br>(0.72) | 20<br>(0.25) |
| 8. | 313 | Mnfg of drugs & medicines | 20<br>(7.17) | 256<br>(3.16) |
| 9. | 321 | Mnfg. of glass & glass products | 1<br>(0.36) | – |
| 10. | 325 | Mnfg. of structural stone goods, stone dressing and stone crushing | 16<br>(5.72) | 170<br>(2.10) |
| 11. | 330 | Iron and steel Industries | 38<br>(13.62) | 4200<br>(51.81) |
| 12. | 36 | Mnfg. of electrical machinery, apparatus and appliances | 4<br>(1.43) | 200<br>(2.47) |
| 13. | 531 | Cement | 3<br>(1.08) | 60<br>(0.74) |
| 14. | | Others | 60<br>(21.51) | 300<br>(3.70) |
| | | Total | 279 | 8106 |

**Source:** District Statistical Hand Book, Alwar – 1984.

### Table - 11 Registered Factories in Delhi : Group-wise – 1985

| Description | Number of Factories | | | | | | | Workers (daily average in '000) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 79 | 80 | 81 | 82 | 83 | 84 | 85 |
| 1. Food Products | 114 | 124 | 130 | 142 | 148 | 153 | 160 | 7 | 9 | 9 | 9 | 9 | 9.5 | 9.7 |
| 2. Textiles & Textiles Products | 457 | 520 | 545 | 622 | 666 | 709 | 746 | 43 | 46 | 46 | 46 | 48 | 50 | 52 |
| 3. Wood Products | 46 | 47 | 52 | 56 | 60 | 66 | 67 | 1 | 1 | 1 | 1 | 1 | 1 | 1.04 |
| 4. Paper Products and Printing | 230 | 223 | 255 | 279 | 290 | 302 | 315 | 11 | 12 | 12 | 12 | 12 | 12 | 12.6 |
| 5. Leather, Rubber & Chemicals | 396 | 429 | 434 | 495 | 534 | 578 | 581 | 12 | 14 | 14 | 14 | 15 | 17 | 17.1 |
| 6. Non-metallic mineral Products | 55 | 57 | 51 | 107 | 114 | 119 | 146 | 4 | 3 | 3 | 3 | 3 | 3 | 3.7 |
| 7. Metal & Engineering Products | 763 | 807 | 856 | 970 | 1032 | 1097 | 1128 | 23 | 26 | 26 | 27 | 29 | 31 | 32.2 |
| 8. Manufacturing of Electrical machinery | 308 | 355 | 374 | 451 | 480 | 530 | 545 | 12 | 14 | 14 | 15 | 16 | 18 | 19.6 |
| 9. Manufacture and other Misc. of Transport Equipment | 393 | 395 | 487 | 555 | 592 | 629 | 653 | 15 | 16 | 16 | 24 | 25 | 27 | 27.5 |
| 10. Generation and Trans. of electricity, water supply and gas. | 21 | 21 | 18 | 21 | 21 | 21 | 21 | 6 | 5 | 5 | 3 | 3 | 3 | 3 |
| 11. Miscellaneous | 201 | 215 | 200 | 219 | 226 | 241 | 290 | 7 | 7 | 7 | 4 | 5 | 7 | 7.3 |
| Total | 2984 | 3193 | 3402 | 3917 | 4163 | 4445 | 4652 | 141 | 153 | 153 | 158 | 166 | 178.5 | 185.74 |

**Source:** Delhi Statistical Hand Books – 1986.

## Table 12 Power Generation Programme in the NCR

| Sl. No. | Schemes (Agency) | Location | Type | Units & rated capacity MW | Installed capacity MW | Expected year of commissioning |
|---|---|---|---|---|---|---|
| | **Existing** | | | | | |
| 1. | Rajghat (DESU) | Delhi | Thermal | 1X15 | 15 | |
| 2. | I.P. Estate (DESU) | Delhi | Thermal | 1X36.6<br>3X67.5<br>1X60 | 284.1* | |
| 3. | Badarpur (NTPC) | Delhi | Thermal | 3X100<br>2X210 | 720 | |
| 4. | I.P. Estate (DESU) | Delhi | Gas | 6X30 | 180 | |
| 5. | Panipat Stage I&II (HSEB) | Panipat | Thermal | 4X110 | 440 | |
| 6. | Faridabad (HSEB) | Ballabhgarh | Thermal | 1X15<br>3X60 | 195 | |
| | | Sub-total | | | 1834.1 | |
| | **Under Construction:** | | | | | |
| 1. | Rajghat (DESU) (replacement units) | Delhi | Thermal | 2X67.5 | 135 | Unit I May 88,<br>Unit II Sept 88 |
| 2. | Panipat (HSEB) Stage III | Panipat | Thermal | 1X210 | 210 | 1987-88 |
| 3. | Kokroi** | Sonepat | Hydel | 3X0.1 | 0.3 | Not known |
| 4. | Narora (APP) | Anupsagar | Nuclear | 2X235 | 470 | £Unit I—1987/88<br>Unit II—1989/90 |
| 5. | Dadri (NTPC) | Ghaziabad | Thermal | 4X210 | 840 | Unit I—1991-92<br>Unit II—1992-93<br>Units III & IV 1993-94 |
| | | Sub-total | | | 1665.4 | |
| | **Proposed** | | | | | |
| 1. | I.P. Estate (DESU) | Delhi | Thermal | 1X210 | 210 | |
| 2. | Panipat Units 4&5 (HSEB) | Panipat | Thermal | 2X110 | 220 | |
| | | Sub-total | | | 430 | |
| | | Grand total | | | 3919.4 | |

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* Includes the share of Haryana of 62.5 MW

** By Alternate Hydro Energy Centre, Roorkee University as an experimental project.

£ Narora Atomic Power Project under central sector is being set up for the benefit of constituent states of the Northern Region. Allocation of power is yet to be decided.

**Sources:** 1. Ministry of Energy/Central Electricity Authority
2. State Power Boards
3. DESU

Table 13 : Traffic movement on major corridors

| Major corridor | Total pass. vehicle | Total buses | Total goods vehicle | Total volume |
|---|---|---|---|---|
| 1. Delhi-Faridabad | 21585 | 1936 | 6795 | 30316 |
| | (71.2) | (6.4) | (22.4) | (100.0) |
| 2. Delhi-Gurgaon | 9407 | 1483 | 415 | 14995 |
| | (62.7) | (9.9) | (27.4) | (100.0) |
| 3. Delhi-Bahadurgarh | 3708 | 753 | 2513 | 6974 |
| | (53.2) | (10.8) | (36.0) | (100.0) |
| 4. Delhi-Panipat | 3383 | 1207 | 3712 | 8302 |
| | (40.7) | (14.5) | (45.8) | (100.0) |
| 5. Delhi-Baghpat | 5056 | 474 | 2371 | 7901 |
| | (64.0) | (6.0) | (30.0) | (100.0) |
| 6. Delhi-Ghaziabad | 28714 | 2605 | 11432 | 42751 |
| | (67.2) | (6.1) | (26.7) | (100.0) |
| 7. Delhi-Noida | 16677 | 1623 | 2007 | 20307 |
| | (82.1) | (8.0) | (9.9) | (100.0) |
| 8. Ghaziabad-Meerut | 7047 | 1089 | 3109 | 11245 |
| | (62.7) | (9.8) | (27.5) | (100.0) |
| 9. Ghaziabad-Hapur | 4176 | 789 | 1906 | 6871 |
| | (60.8) | (11.5) | (27.7) | (100.0) |
| 10. Ghaziabad-Bulandshahr | 6110 | 768 | 2141 | 9019 |
| | (67.8) | (8.5) | (23.7) | (100.0) |
| 11. Gurgaon-Behror(NCRB) | 2021 | 613 | 4036 | 6670 |
| | (30.3) | (9.2) | (60.5) | (100.0) |

Table 14 : Generation of passenger traffic (daily) for NCR and important urban areas

| Urban Zone/ NCR | Vehicle Passengers | Bus Pass. | Rail Pass. | Total | Rail Share(%) |
|---|---|---|---|---|---|
| DUT | 58794 | 173722 | 107000 | 339516 | 32 |
| | (25.3) | (39.3) | (50.9) | | |
| Ghaziabad | 17465 | 32298 | 32856 | 82619 | 40 |
| Noida | 9300 | 31026 | - | 40326 | - |
| Faridabad | 16505 | 24675 | 6568 | 47748 | 14 |
| Meerut | 17368 | 34242 | 420 | 61030 | 15 |
| Rohtak | 18200 | 20845 | 5197 | 44242 | 12 |
| Bulandshahr | 13460 | 23522 | 2644 | 39626 | 7 |
| Total NCR (generated by internal zones) | 232000 | 442000 | 210000 | 884000 | 24 |
| Total movements in NCR (including external zones and through traffic) | 248100 | 540000 | N.A. | | |

**Table 1.5 Indices of goods traffic generation and attraction – Selected urban centres**

| Town | Total Traffic (Tonnage) | | Index | | Index of 1987 Population | Index of Industrial* Employment |
|---|---|---|---|---|---|---|
| | Attracted | Generated | Attracted | Generated | | |
| Ghaziabad | 25995 | 23415 | 100.00 | 100.00 | 100.00<br>(5.44 lakhs) | 100.00<br>(55510) |
| NOIDA | 4605 | 2165 | 18.00 | 9.25 | 40.00 | NA |
| Faridabad | 4738 | 9676 | 18.5 | 41.50 | 98.00 | 190.00 |
| Gurgaon | 2253 | 2845 | 8.50 | 12.00 | 52.00 | 18.00 |
| Bahadurgarh | 1252 | 1721 | 5.00 | 7.50 | 16.00 | 8.00 |
| Meerut | 5705 | 2210 | 22.00 | 9.50 | 140.00 | 15.00 |
| Hapur | 3281 | 2489 | 12.70 | 10.70 | 28.00 | 3.00 |
| Bulandshahr | 1710 | 1705 | 6.60 | 7.30 | 46.00 | 5.00 |
| Palwal | 691 | 824 | 2.70 | 3.50 | 14.00 | 15.00 |
| Panipat | 5724 | 880 | 22.00 | 3.75 | 46.00 | 30.00 |
| Rohtak | 4004 | 2169 | 15.50 | 9.25 | 50.00 | 4.50 |
| Rewari | 648 | 829 | 2.50 | 3.50 | 24.00 | 7.50 |
| Alwar | 4438 | 1681 | 17.00 | 7.20 | 47.00 | - NA |
| Sonepat | 1553 | 1054 | 6.00 | 4.50 | 29.00 | 25.00 |

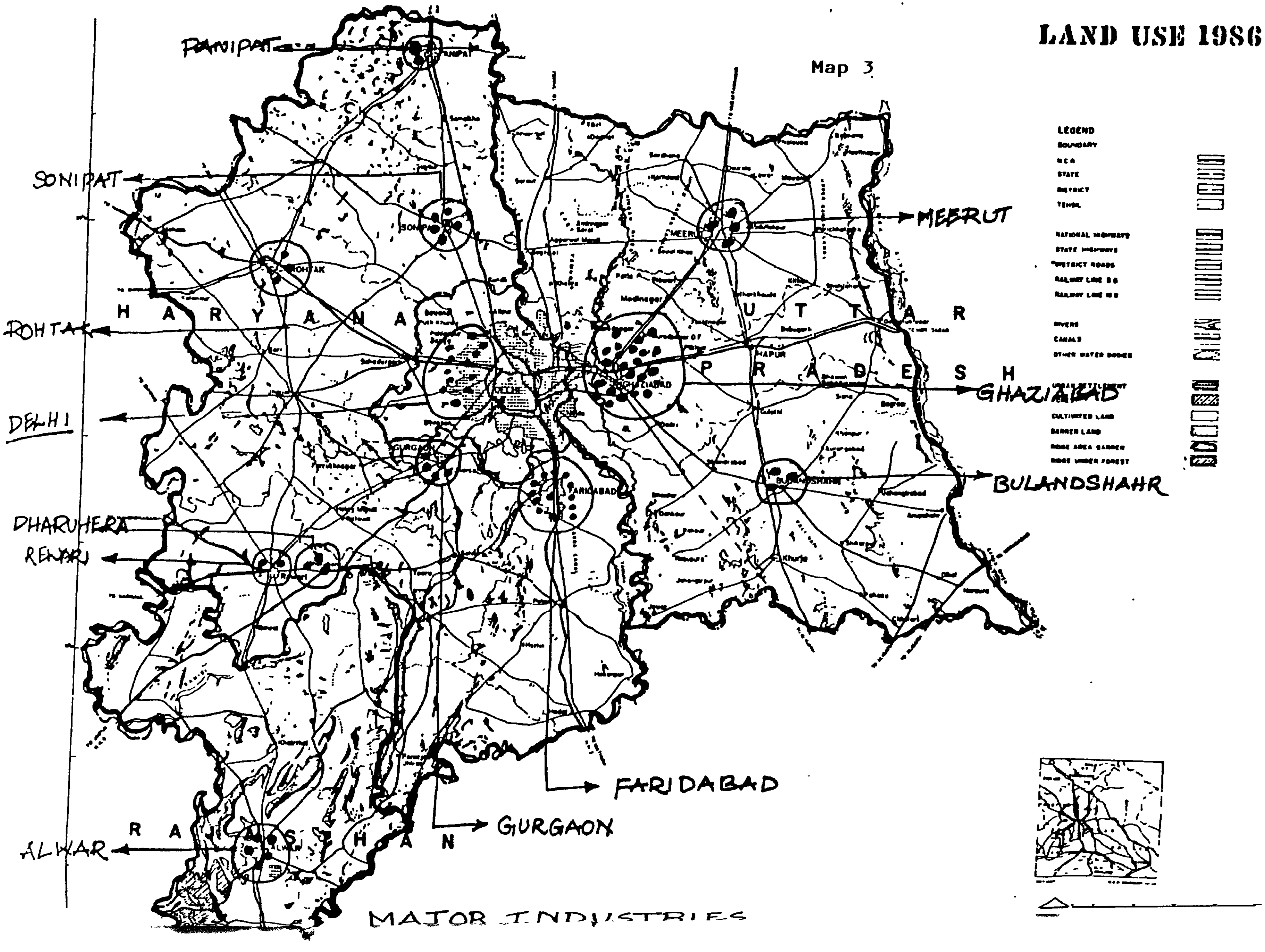
*1. Coverage of industrial employment is uniform in all urban areas, particularly in terms of employment in small industries.

2. In view of varying growth rate of industrial employment between 1981 and 1987 among different urban areas, (e.g., higher growth rate in Ghaziabad, Hapur, Panipat and Bahadurgarh during the period), correlation between 1981 index of industrial employment and that of traffic (1987) is not always appropriate.

**LAND USE 1986-87**

**LAND USE 1986-8**

Map 3



MAJOR INDUSTRIES

## Uttar Pradesh Subregion

Of the 1351 registered factories in the UP subregion in 1983-84 Gaziabad district alone had 60.11% of them. Of the rest Meerut district accounted for 28.25% and Bulandhhahr district 10.64% (Table 9).

## Rajasthan Subregion

There were in all 279, registered factories in Alwar district by 1983 and there are at present 30 large, 28 medium scale units in the district, of which 27 large and 27 medium scale units are in the subregion. The major concentration of large and medium scale industries has been at Alwar followed by Bhiwadi. Out of27 large scale industries in the district, 19 are located in Alwar, seven in Bhiwadi and only one in Behror. Similarly, out of 27 medium scale units, 19 units are located at Alwar and rest of the light at Bhiwadi (Table 10).

## Delhi Union Territory

The number of factories registered in 1985 stands at 4652 and is showing a rapid growth (Table 11).

After looking at the location and type of industries in the region, the energy intensive, highly pollutant industries are identified and are marked on a map. Map 3 shows clusters of major polluting industies in NCR. Table 16 gives a break up of the various industries located in the NCR, with their capital outlay.

## Table 16: Location of Various Industries in the NCR with Their Capital Outlay

| Location | Products | Sales/Capital Outlay (Rs. Crores) |
|---|---|---|
| Faridabad | Paper Pulp | 2.13 |
| | Footwear Accessories | 15.35 |
| | Carbon Steel Ingnots | 6.61 |
| | Gray Cloth | 30.00 |
| | Motor Cycle, Scooter and Agrl. Tractors | 99.49 |
| | Ford 3600 tractors, diesel engines, and components | 59.12 |
| | Steel wires | 7.10 |
| | Steel Wires, Bright bars, Strained Wires | 6.47 |
| | Steel Pipes & Tubes and Synthetic Yarn | 26.67 |
| | Refrigerators, Deep Freezers additional compressors | 64.43 |
| | Cotton Yarn | 5.06 |
| | Ingots, rolled products | 12.46 |
| | PVC insulated cables, railway signalling cables | 10.00 |
| | Sugar Mill | 9.60 |
| Ballabhagarh | Automative Tyres | 87.69 |
| | Asbestos Cement Sheet, Pipes, and Fitting, Asbestos Mill Baord | 35.45 |
| Gurgaon | Passenger Cars, and Engines | 4.05 |
| | Fertilizer Products | 5.50 |
| | Passenger Cars (under erection) | 269.00 |

Contd.../-

Table 16 Contd...

| Location | Products | Sales/Capital Outlay (Rs. Crores) |
|---|---|---|
| Panipat | Urea | 99.68 |
| | Sugar | 5.77 |
| IOL (Karnal) | Petroleum Products | 1360.00 |
| Rewari | Automobile Equipment Projects | 14.00 |
| | Bll Bearing Project | 25.00 |
| Rohtak | Sugar | 7.22 |
| Bahadurgarh | Sanitary Wares Refractories, Glass Bottles, and Tumblers | 17.65 |
| | Pipes & Tubes, Welding Heads & Aluminium Alloy | 21.65 |
| | Glazed Tiles | 13.93 |
| Sonepat | Bicycles & Powered Bicycles | 44.53 |
| | GLC Lamps, Fluorescent Tubes, Mercury Vapour Lamps, Transformers | 11.75 |
| Mirthar | M.S. Ingots, rolled products, Oxygen | 13.26 |
| Ganaur | Steel Pipes, and Tubes | 25.93 |
| Amarnagar | Steel Ignots | 6.91 |
| Dharuhera | Hero Honda Motor | 43.00 |
| Bahalgarh | Refined Oil | 3.61 |
| Kindli | Vanaspati, Refined OIl | 5.86 |
| Bulandshahr | Fertilizer Project | 6.00 |
| Sikanderabad | Cotton and Synthetic Blended Yarn | 6.85 |
| | Storage Batteries | 13.02 |
| Salempur | Yamaha Motor Cycle Project (under erection) | 40.00 |

Contd.../-

Table 16 Contd...

| Location | Products | Sales/Capital Outlay (Rs. Crores) |
|---|---|---|
| | Styrene Project | 27.00 |
| Gaziabad | Yarn | 6.9 |
| | Steel Pipes & Tubes | 18.98 |
| | Vegetable Products, Refined Oil | 88.82 |
| | Iron & Steel Produces | 10.00 |
| | Steel Ingots, Billets | 5.76 |
| | Processed Hydrogenated Oils, Vanaspati Ghee | 11.33 |
| | Vanaspati-Soap, Refined Oil | 29.16 |
| | Hydrogenated Oil, Vanaspatic Animal Feeding Stuff | 39.93 |
| | Carbon Black | 19.91 |
| | Mild Steel, Carbon & Alloy Steel Ingots built Rolled Products | 11.67 |
| | Polyester Staple Fibre, Methanol Products | 45.95 |
| | Toilet Soaps, Washing Soaps, Animal Feeds, Vanaspati | 26.81 |
| Dairala Mawana | Sugar, Alcohols | 73.31 |
| Modinagar | Nylon Filament Yarn, Viscose Staple Yarn | 98.85 |
| | Sugar, Vanaspati, Country Liquor, Washing Soap | 95.03 |

Table 16 Contd...

| Location | Products | Sales/Capital Outlay (Rs. Crores) |
|---|---|---|
| Meerut Road | Steel Tubes, PVC Pipes | 39.94 |
| Simbhadi | Sugar | 12.90 |
| Alwar | Medium/Heavy Duty Vehicles | 28.00 |
| | Sulphuric Acid | 7.10 |
| | Tractors, Diesel Engine | |
| | Caustic Soda, Liquid Cl, $H_2SO_4$, HCl, Bleaching Powder | 14.91 |
| | Mild Stee, High Carbon, Alloy Steel Ingots, Billets and rolled Products | 8.49 |
| | Commercial Vehicle Project (under erection) | 102.00 |
| | Scooter Project (under erection) | 25.00 |
| | Filamess Projects (under erection) | 7.23 |
| | Fluorescent Tubes Project (under erection) | 10.00 |
| Delhi | Cloth Yarn, Sugar, Vanaspati Oil, Caustic Soda | 242.52 |
| | Air Conditioners & Refrigerators | 40.00 |
| | Vegetable Gheee, Electric Fans | 36.11 |
| | Cloth & Yarn | 10.80 |
| | Lamps GLS, Shells & Tubes, Filament Fluorescent Powder | 25.50 |
| | Air Conditioning Equipments | 15.00 |

## 2.4 POWER

Electricity, is one of the most important forms of energy and it is indispensable for the development of industry and agriculture, power generation is a major source of pollution of Atmosphere.

### 2.4.1 Power Generation

**Existing**

The NCR falls within the northern power zone and has in operation six power generation stations. __ five thermal and one gas fired located within its boundaries. Three stations lie in the Delhi UT run by the Delhi Electricity Supply undertakings (DESU) and the rest three in the Haryanas portion of the NCR. The subregions of Uttar Pradesh and Rajasthan do not have any power generating stations located within them. The aggregate installed capacity of these generating stations is 1934.1 MW.

**Under Construction**

Five power plants with a total installed capacity of 1665.3 MW are under construction in the region. Of them, three are thermal, one hydro and one nuclear. Thus, the total installed generating capacity by the end of 1995 in the NCR would be around 3489 MW.

**Proposals**

Two more extension schemes with a total installed capacity of 430 MW are anticipated to come up in the near future in the region. The aggregate installed capacity of all the 13 generating stations will be of the order of 3920 MW.

Table 11 gives the power generation programmes in the region (Fig. 4, 5).

## 2.5 TRANSPORT

Transport development in National Capital Region has been esentially corridor oriented. Thee are nine corridors in NCR which form the backbone of the region.

The major transport corridors of movement with Delhi are:

1. Delhi-Ghaziabad-Meerut
2. Delhi-Ghaziabad-Hapur-Garmukhteshwar
3. Delhi-Ghaziabad-Sikanderabad-Bulandshahr
4. Delhi-Faridabad-Palwal-Hodal
5. Delhi-Gurgaon-Palwal-Behroor
6. Delhi-Gurgaon-Sohana-Mah-Alioa
7. Delhi-Bahadurgarh-Rohtak-Mah
8. Delhi-Sonepat-Panipat
9. Delhi-Loni-Baghpat-Baraut

### 2.5.1 Road Network

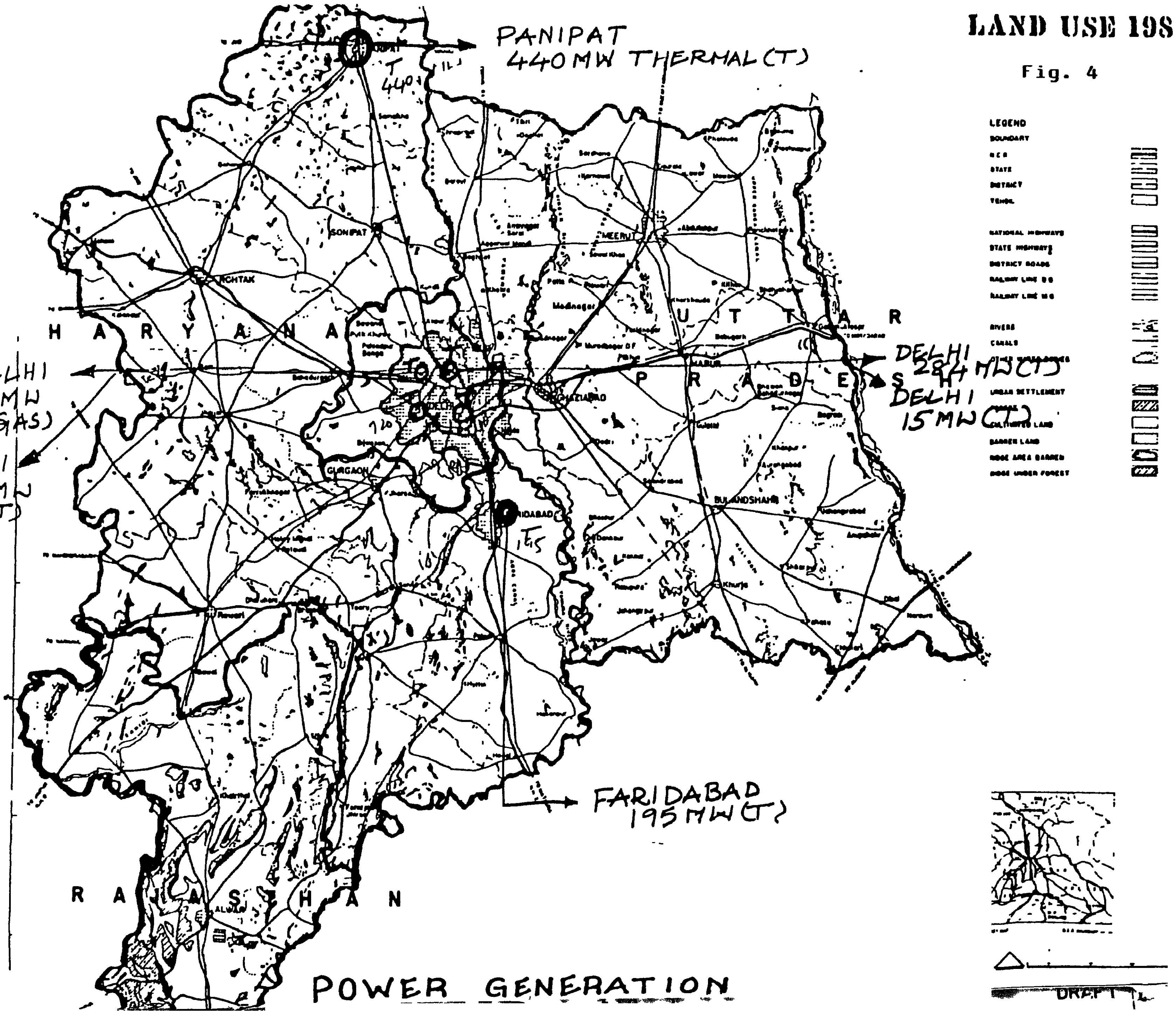
The road network in the NCR shows a convergence towards Delhi, with the five National Highways NH1, NH2, NH8, NH10, NH24 terminating at Delhi.

### 2.5.2. Rail Network

The rail network in the NCR consists of a mix of gauges and is highlighted by its being the converging point of 5

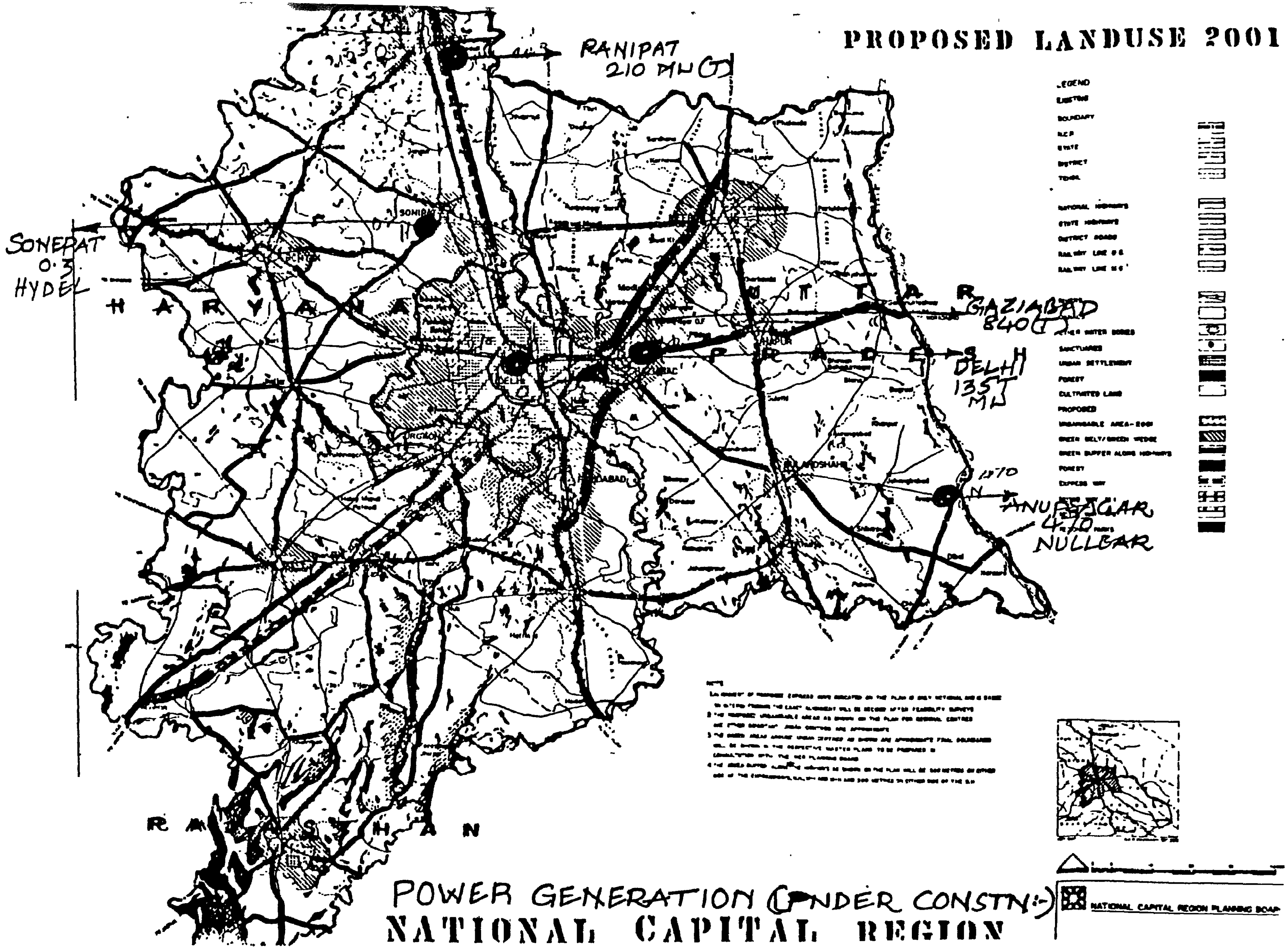
**LAND USE 1986-8**

Fig. 4



POWER GENERATION

# PROPOSED LANDUSE 2001



POWER GENERATION (UNDER CONSTN:-)

# NATIONAL CAPITAL REGION

railway lines. The NCR rail network covers three zonal railways (Northern, Western and Central) and 5 division, six bulk commodities, viz. coal, foodgrains, petroleum products, cement, fruits and vegetables and iron and steel are handled by trains. Due to convergence of major regional trains at Delhi and lack of loading and unloading facilities of DMA towns, Delhi has become major distribution case for NCR. Coal movement to the three power stations in Delhi account for 7 to 8 train loads a day.

### 2.5.3. Traffic flow characteristics in the NCR

The road network as described earlier focuses on Delhi as the major centre in the region. The major corridors are Delhi-Ghaziabad, followed by Delhi-Faridabad and Delhi-Gurgaon. Other important ones are Ghaziabad-Meerut and Ghaziabad-Bulandshahr (Table 13) (Fig.7).

The total daily movement of bus passengers and other vehicle passengers in the NCR in 1987 is about 5.4 lakhs and 2.25 lakhs respectively. Table 14 gives attraction and generation of passenger traffic volume and per capita trip generation rate in NCR urban areas (Fig.7).

#### Goods Movement

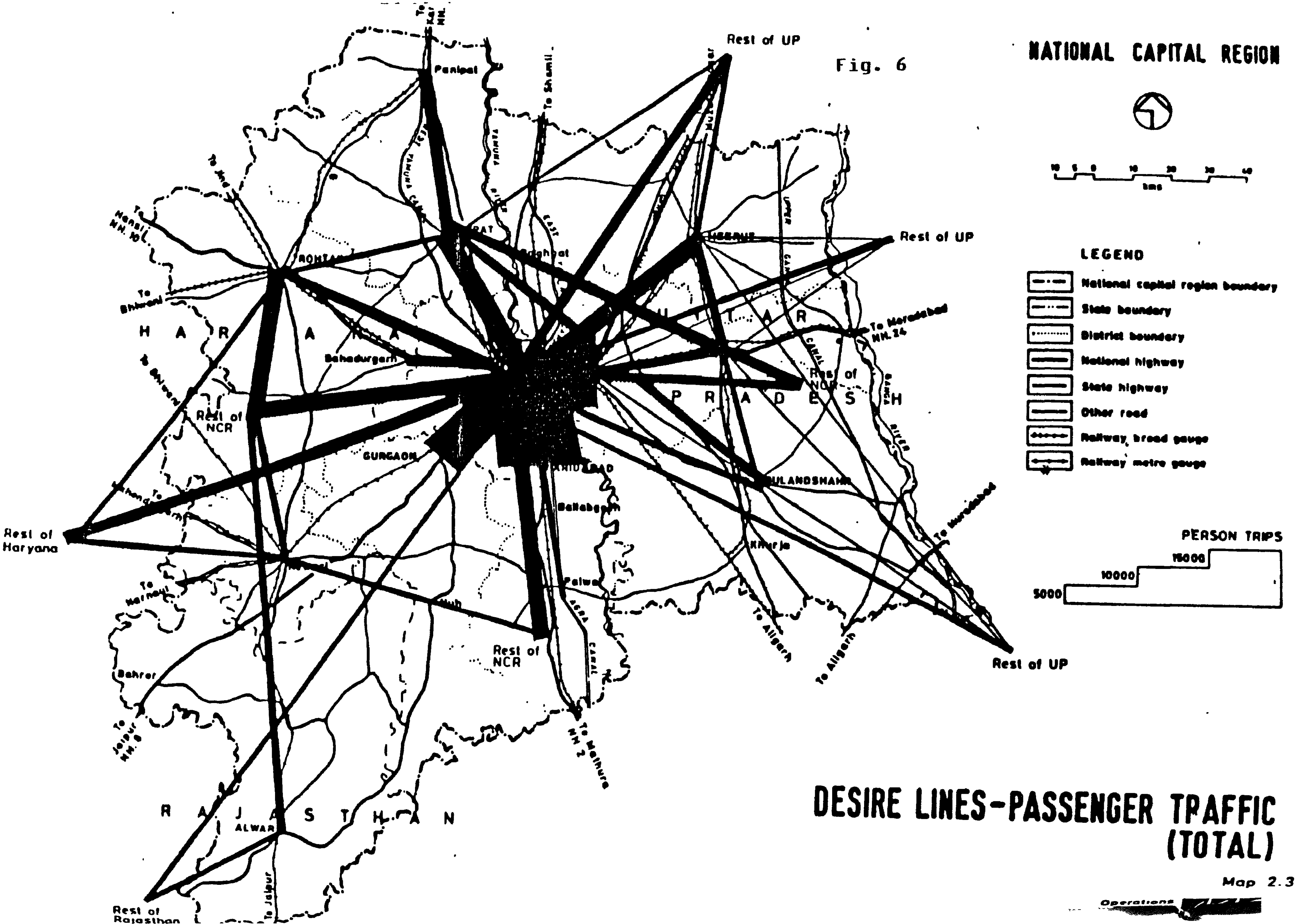
The total daily movement of goods in the NCR is about 1.92 lakh tonnes. Only abot 32% of the total tonnage moved is found to be intra-regional 63% interregional, the through component accounting for 4%. The goods movement shows

Ghaziabad as the only other significant case of attraction within the NCR next only to Delhi (Table 15) (Fig. 8).

## 2.6 CONCLUSIONS

The above characteristics show that the road system plays a much important role both in passenger and goods movement. Rail accounts for 15% of goods traffic (inward) and 38% of the passenger traffic (generation) by public transport. The rail flows are important only in certain corridors. Except for Ghaziabad, there is no other significant centre for attraction in terms of goods traffic. In terms of passenger traffic, DNA towns account for a large proportion of movement with Delhi (about 60%) and only other significant linkages are with Meerut.

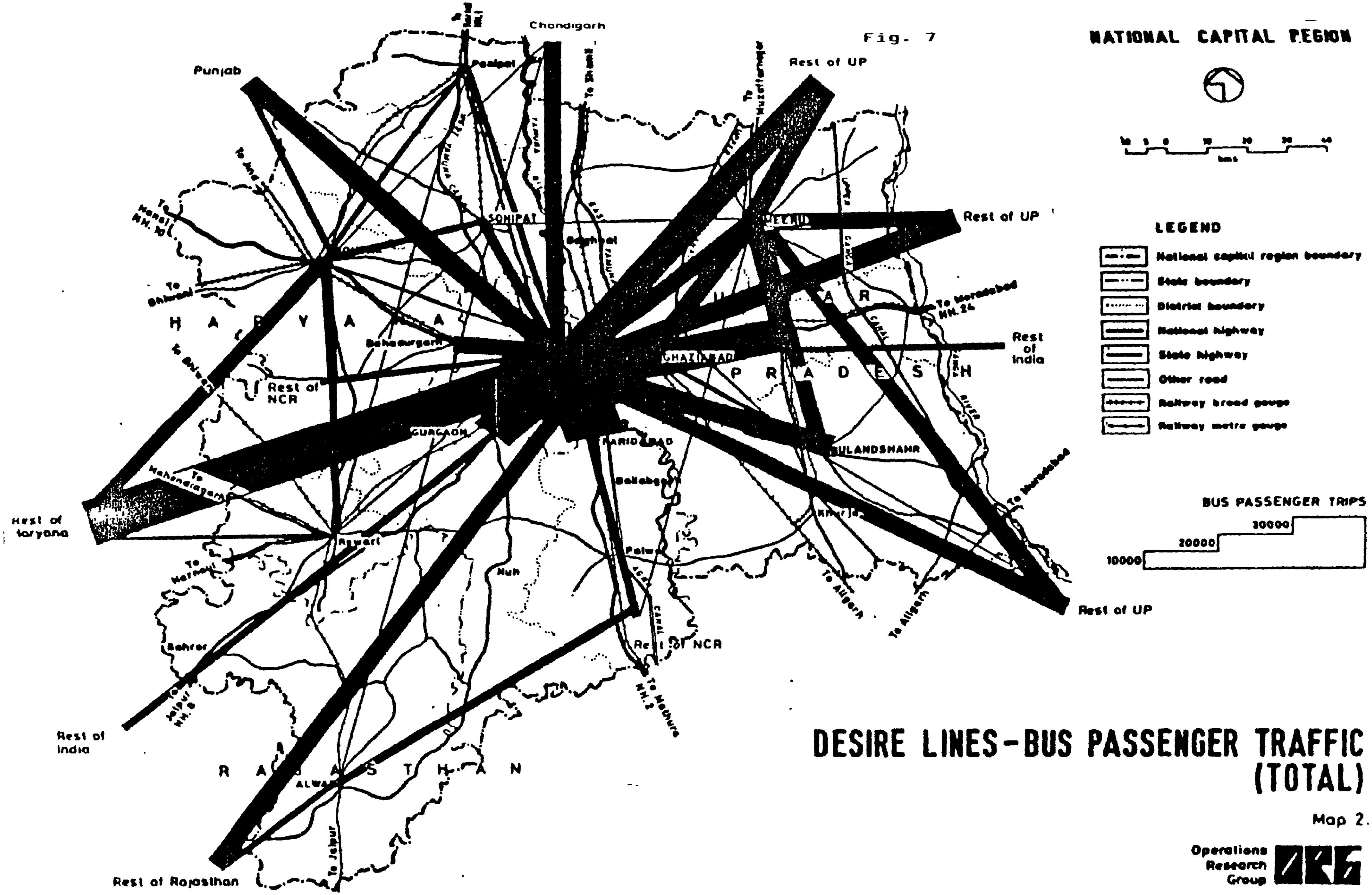
Fig. 6



# DESIRE LINES-PASSENGER TRAFFIC (TOTAL)

Map 2.3

Fig. 7

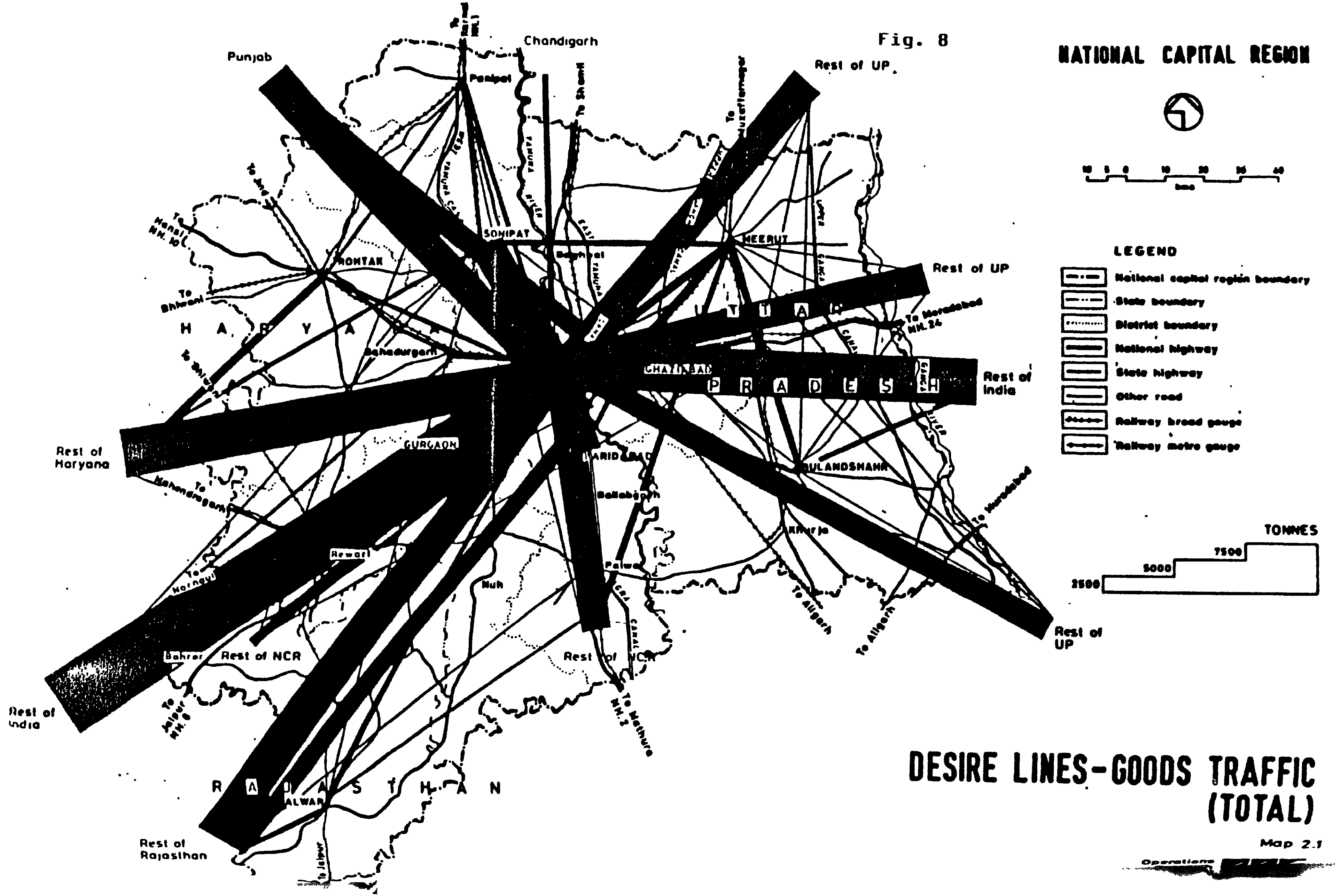


# DESIRE LINES-BUS PASSENGER TRAFFIC (TOTAL)

Map 2.2

Operations Research Group

Fig. 8


NATIONAL CAPITAL REGION
km
LEGEND
National capital region boundary
State boundary
District boundary
National highway
State highway
Other road
Railway broad gauge
Railway metre gauge
TONNES
7500
5000
2500
Punjab
Chandigarh
Rest of UP.
Rest of UP
Rest of India
Rest of UP
Rest of Haryana
Rest of India
Rest of NCR
Rest of NCR
Rest of Rajasthan
Panipat
SONIPAT
ROHTAK
MEERUT
GHAZIABAD
FARIDABAD
Ballabgarh
Palwal
GURGAON
Bahadurgarh
Rewari
Bahror
Nuh
ALWAR
BULANDSHAHR
Khurja
To Shamli
To Muzaffarnagar
To Moradabad NH.24
To Moradabad
To Aligarh
To Aligarh
To Mathura NH.2
To Jaipur NH.8
To Jaipur
To Narnaul
To Mahendragarh
To Bhiwani
To Bhiwani
To Hansi NH.10
To Jind
H A R Y A N A
U T T A R
P R A D E S H
R A J A S T H A N
YAMUNA RIVER
EAST YAMUNA CANAL
WEST YAMUNA CANAL
UPPER GANGA CANAL
GANGA RIVER
AGRA CANAL
DESIRE LINES-GOODS TRAFFIC (TOTAL)
Map 2.1
Operations

## 3.0 MATHEMATICAL MODELLING

### 3.1 INTRODUCTION

In this section we describe the approach we use to model the contribution of pollutants by the major sources in the national capital region (NCR). The approach we use is phased one. A basic core structure for the model will be established in the first phase. This will be such that modifications and additions can be incorporated with ease.

### 3.2 PHASE 1 - LINEAR DISPERSION MODEL (NEGLECTING WIND EFFECTS)

The model in this starting phase will be a simple linear model. The primary effect of pollutant dispersion will be accomplished by molecular diffusion. At this stage we neglect all wind effects. The various source terms which will be considered include industrial plants, power plants, vehicle emissions and domestic sources as described in Section 1. The pollutants we will consider in order of decreasing importance are CO, $SO_x$ (oxides of sulphur), $NO_x$ (oxides of nitrogen), hydrocarbons, suspended particle matter. Importance will be given to the first three pollutants. Among the sources, industrial plants and power plants will be treated as point sources. Vehicle emissions and domestic sources will be taken into account as area sources. The point sources will be considered in the domain and the area sources will be incorporated along the boundary at the ground level.

Since we are considering the whole NCR, the next question of importance is the grid size. This will be determined by the strength of the various sources. The radius of influence of each source will be calculated, to study the distance over which the source has any effect. The grid we choose will be non-uniform. The sizes will be determined by the respective sources, and their strengths present in the sub-regions of interest. This involves calculating the influence of each source as an initial value problem, to enable us to get a preliminary estimate on the grid size. If the grids can be chosen to be bigger than this region each grid can be isolated from its neighbouring grids. In the event that this is not possible the interaction between the grids will be considered. This can be done by taking into account effective mass transfer coefficients between the sub-regions. This determines the direction of flux between the various grids. The region we will consider is three dimensional. The NCR will be modelled as a rectangular region for purposes of simplicity. The height over which the domain of interest extends is the inversion layer [3]. At this height we can have no flux of the pollutants and we model this as an impenetrable membrane. The basic form of the equation is:

$$\frac{C_i}{t} = D_i \quad C_i + f(C_i, x)$$

with the boundary conditions at $z = 0$, $-\frac{d\,C_i}{dz} = g\,(C_i, t)$

$$z = h, \quad \frac{d\,C_i}{dz} = 0$$

Here $C_i$ represents concentration of pollutant i, D the diffusion coefficient, f represents the source terms in the domain, g is the source term due to vehicle emissions and domestic emissions. Note that f depends on position explicitly and g on time [2, 4]. As mentioned earlier we will try and solve these equations for various i's (pollutants), and domains using an initial value approach to determine the region effected by the sources.

A system, as the one under consideration with production terms scattered along the boundary as well as in the domain, with no flux boundary conditions, will be such that the total concentration of pollutants will increase in the domain with time. Hence, it is necessary to include depletion terms which will decelerate pollutant build up. Foliage acts as a good deterrent to the build up process, as it serves as a good adsorbent for most pollutants [1]. It serves to effectively increase the deposition velocity. Another mechanism which deletes the pollutants can be by considering chemical reactions in the domain of the equations.

As explained earlier the primary effect we will consider at this stage of the model is molecular diffusion. This ensures dispersion occurs symmetrically around a source. Wind effects primarily serve to skew this symmetric distribution in a preferred direction.

An advantage of the simple linear model proposed here is its easy extendability. This ensures its easy extension to include the effects of different sources without many complications. The simple linear partial differential equation:

$$\frac{u}{t} = D \frac{u}{x^2}$$

with initial condition as a unit source at the origin in an infinite domain has the solution.

$$U_0 (x, t) = \frac{1}{4 \pi Dt} e^{-\frac{x^2}{4 Dt}}$$

This $U_0$ is a unit source solution, and gives us the distribution of the unit mass of pollutant at origin at time t between x and x + dx [6]. This is a fundamental solution. The differential equation is invariant when x,t are changed into $x-\alpha$ and $t-\beta$. This can be verified by direct substitution. Hence, $U_0(x-\alpha, t-\beta)$ is a solution to the diffusion equation for a source at time $\beta$ and position $\alpha$, since the equation is linear.

Thus, if $C_1$, $C_2$ represent the strengths of two sources at positions $x_1$, $x_2$, the net effect can be obtained by considering the overall distribution u as [6]:

$$u = C_1 U_0 (x-x_1, t) + C_{21} U_0 (x-x_2, t)$$

Thus, this approach at the preliminary stage although simplistic can enable us to consider the effect of various sources as a simple add on effect, analytically. This is the real advantage of the proposed linear model. Once we obtain a preliminary idea about the effect, we can get into more complicated model.

The other important problem is that we have a finite domain. This makes it essential to include boundary conditions. In an infinite domain, the standard boundary conditions used are the no flux conditions in the direction extending to infinity. This may not be realistic in the NCR. Although the region is widespread (32,242 sq. kms.) the various sources are widespread through out the domain. Moreover, the boundary conditions will be determined by the sources present in a close neighbourhood of the NCR boundary, including the region outside the NCR. We are fortunate, however, in the fact that almost all major sources of pollution are present well in the interior of the NCR. The initial value approach permitting me might then be able to perhaps consider no flux conditions along the NCR boundary. The model in this phase will be purely fundamental. No empiricism will be involved. The inputs to the model will come from the data collected. This is discussed in section 3.

## 3.3 PHASE 2 - LINEAR MODEL (CONSTANT WIND VELOCITY)

The additional effect we would consider in this phase is the wind velocity. This will be treated initially as an add on effect to the diffusivity giving rise to an effective diffusivity $D_{eff}$. The wind velocity effect will also be considered separately as a convective term. Here its diurnal and seasonal fluctuations will be considered.

The inclusion of wind velocity effects brings out picture an important and significant effect. We retain the simplicity of the model by considering wind velocity to be a constant. However, we have an interesting mathematical problem since, there is a wide range of time scales present [5]. Thus, we have wind velocity fluctuations every 12 hrs., vehicle emissions fluctuating every 12 hrs. The industrial emissions and power plant emissions are continuous and constant sources. The seasonal variation of wind velocity occurs every 6 months. To consider the interesting mathematical problem posed by the presence of this wide time scale ranges present we will use the perturbation method based on a multiple time scale approach. This will once again give us preliminary ideas on the physics of the problem. We can use these results as a basis to develop a more complicated model.

### 3.4 DATA NEEDS

Data has been collected and is being collected, see (Section 3). The different data enters the model in various ways. The strengths of the various source terms and will be obtained, and serve to remove empiricism from the model. For the case of industrial emissions, the emissions are related to the production capacity of the industry. The same is true for powerplants. There have been numerous studies in the case of powerplants which have related the emissions to the powerplant capacity.

The domestic emissions are related to the population in a region. Here again data is available. For the different kinds of vehicles, estimates of the various emissions sources is available (see Section 3).

All constants will be evaluated from the literature. The various parameters which occur in the model are the diffusion coefficients. The gas phase coefficients are tabulated in the literature and we will use them. This empiricism will be avoided completely. The height of the inversioin layer will be got from the various correlations available in the literature. Concentration profiles as predicted by the model will also be compared to data available.

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## 4.0 INPUTS TO THE MODEL

The accuracy of the model primarily depends on the source and emission inventories. $SO_x$, $NO_x$, SPM, CO and HCs are the major emissions from various possible sources that has been taken into consideration as input in the model. Major sources of $SO_x$ over the National Capital Region (NCR) are:

a) Domestic coal burning

b) Industrial sources (coal or fuel oil)

c) Vehicular traffic

d) Railway shunting yards

e) Power plants

Major sources of $NO_x$ considered in this study are:

a) Vehicular traffic

b) Industries

Major Sources of SPM are:

a) Vehicular Traffic

b) Industries

c) Power plants

CO and HCs are mainly emitted from domestic wood burning and vehicular traffic.

The fall out pattern, ambient and ground level concentrations of pollutants depend upon the meteorological conditions, especially wind direction and speed and vertical and horizontal thermal gradient prevailing in the area. Therefore, some meteorological parameters has also been considered as input in the model.

As discussed earlier different sources (point and area) has been identified over the NCR and classified into main four categories. These are:

a) Domestic

b) Industries

c) Vehicular traffic and

d) Power plants

## 4.1 DOMESTIC

Let us consider domestic first:

Wood is the most commonly used fuel in domestic cooking; however, coal and other fuels (LPG, Kerosene etc.) are also used for cooking in the NCR.

The major pollutants of concern are unburnt combustibles - carbon monoxide and smoke. Because most wood contains negligible sulphur, very few sulphur oxides are emitted but when coal is burned sulphur oxides will be produced. Nitrogen oxide emissions are expected to be negligible because of the low combustion temperatures involved.

The total emissions of the pollutants from domestic fuel burning are calculated on the basis of three parameters: (i) per capita energy consumption, (ii) total population and (iii) emission factors. Table 1 [1] and 2 [2] depict the total population pattern over NCR and emission factors for different pollutants respectively.

## Table 1: Total Population Pattern over NCR

| Order of Towns | | Sub-region | Population ([illegible]) |
|---|---|---|---|
| 1. | Meerut | Uttar Pradesh | 536615 |
| 2. | Ghaziabad | Uttar Pradesh | 287170 |
| 3. | Faridabad Complex Administration | Haryana | 330864 |
| 4. | Rohtak | Haryana | 166767 |
| 5. | Alwar | Rajasthan | 145795 |
| 6. | Panipat | Haryana | 137927 |
| 7. | Sonipat | Haryana | 109369 |
| 8. | Bulandshahr | Uttar Pradesh | 103436 |
| 9. | Gurgaon | Haryana | 100877 |
| 10. | Modinagar (UA) | Uttar Pradesh | 87665 |
| 11. | Hapur | Uttar Pradesh | 102837 |
| 12. | Khurja | Uttar Pradesh | 67119 |
| 13. | Shikarpur | Uttar Pradesh | 21499 |
| 14. | Mawana | Uttar Pradesh | 37620 |
| 15. | Baraut | Uttar Pradesh | 46292 |
| 16. | Rewari | Haryana | 51562 |
| 17. | Pilkhua | Uttar Pradesh | 37884 |
| 18. | Sikandrabad | Uttar Pradesh | 43135 |
| 19. | Murad Nagar | Uttar Pradesh | 26047 |
| 20. | Bahadurgarh | Haryana | 37488 |
| 21. | Palwal | Haryana | 47328 |
| 22. | Pahasu | Uttar Pradesh | 9016 |
| 23. | Khekhada | Uttar Pradesh | 24984 |
| 24. | Jahangirabad | Uttar Pradesh | 29301 |
| 25. | Gohana | Haryana | 26188 |
| 26. | Gulaothi | Uttar Pradesh | 24416 |
| 27. | Sardhana | Uttar Pradesh | 30138 |
| 28. | Debai | Uttar Pradesh | 22430 |
| 29. | Jhajjar | Haryana | 24247 |
| 30. | Siana | Uttar Pradesh | 22410 |
| 31. | Ganaur | Haryana | 16489 |
| 32. | Bawal | Haryana | 7760 |
| 33. | Faridnagar | Uttar Pradesh | 9116 |
| 34. | Baghpat | Uttar Pradesh | 17157 |

Table 2: Emission Factors for Domestic Fuel Burning

| Sl. No. | Pollutant | Wood (Kg/MT) | Coal (Kg/MT) | LPG (Kg/$10^3$ liters) | |
|---|---|---|---|---|---|
| | | | | Butane | Propane |
| 1. | Particulate | 10 | 15 | 0.23 | 0.22 |
| 2. | Sulphur Oxides | 0 | 36 S[a] | 0.015 | 0.015 |
| 3. | Nitrogen Oxides | 1 | 3 | 1.0 | 0.8 |
| 4. | Hydrocarbons | 5 | 20 | 0.096 | 0.084 |
| 5. | Carbon Monoxide | 120 | 90 | 0.24 | 0.23 |

[a] S is the sulphur content, on a weight percent basis, of the coal.

## 4.2 INDUSTRIES

There are a number of industrial complexes in the region at places such as Sonepat, Panipat, Gurgoan, Rohtak, Bahadurgarh, Faridabad and Dharuhera in the Haryana sub-region; NOIDA, Khurja, Bulandshahr, Hapur, Meerut, Modinagar, Muradnagar and Ghaziabad in the Uttar Pradesh sub-region; Alwar and Bhiwadi in the Rajasthan sub-region; and Najafgarh, Lawrence Road, Wazirpur, Kirti Nagar, DLF, Moti Nagar and Okhla in the Union Territory of Delhi.

The major pollutants from industries are mainly $SO_x$, $NO_x$ and SPM. The total emissions depend upon the amount and type of fuel and emission factors (which depend on the process involved). Emission data from industries are sparse. It is, therefore, necessary to make estimates of emission factors on the basis of material balances, yields or similar processes. Table 3 [2] shows the emission factors of different fuels.

Table 3: Emission Factors for Industrial Fuels

| Sl. No. | Pollutant | Bituminous Coal Pulverised | Bituminous Coal Spreader Stoker | Fuel Oil ($Kg/10^3$ litres) Residual Oil | Fuel Oil ($Kg/10^3$ litres) Distillate Oil |
|---|---|---|---|---|---|
| 1. | Particulate | 8 A[b] | 6.5 A[b] | - | 0.25 |
| 2. | Sulphur Di-oxide | 19 S[a] | 19 S[a] | 19 S[c] | 17 S[c] |
| 3. | Sulphur Tri-oxide | - | - | 0.25 S[c] | 0.25 S[c] |
| 4. | Nitrogen Oxides | 9 | 7.5 | 7.5 | 2.8 |
| 5. | Hydrocarbons | 0.15 | 0.5 | 0.12 | 0.12 |
| 6. | Carbon Monoxide | 0.5 | 1 | 0.63 | 0.63 |

[a] S is the sulphur content, on a weight percent basis, of the coal.

[b] A is the ash content, on a weight percent bais, of the coal.

[c] S is the sulphur content, on a weight percent basis of the oil.

For the Union Territory of Delhi, an emission inventory of the air polluting industries with their estimated quantities of $SO_x$ and particulate matter emissions is prepared and shown in Table 4 [3]. For Haryana, U.P. and Rajasthan the inventories would be prepared after collecting the data (no. of industry and their type and capacity) from the corresponding pollution control board.

Table 4: Emission Inventory of $SO_x$ and Particulate Matter for Different Industrial Area over Delhi

| Sl. No. | Industrial Areas | No. of Industrial Units | Emission/Month (Tonnes) Sulphur-Dioxide | Emission/Month (Tonnes) Particulate Matter |
|---|---|---|---|---|
| 1. | Najafgarh Road | 32 | 75.3 | 794.5 |
| 2. | Lawrence Road | 27 | 20.4 | 140.2 |
| 3. | Wazirpur | 90 | 18.2 | 254.1 |
| 4. | Kirti Nagar | 14 | 3.0 | 66.1 |
| 5. | DLF | 15 | 2.1 | 55.7 |
| 6. | Moti Nagar | 3 | 1.1 | 33.4 |

## 4.3 VEHICULAR TRAFFIC

Map - shows the entire transport network in the NCR and is fairly well developed. The radial oriented road network has nine major corridors which forms the backbone for the traffic movement in the region. Delhi is the focal point of the region with 5 national highways covering into it. To have a better understanding of the traffic intensity on different road links covering all important centres in NCR, Table 5 [4] has been prepared and shows the traffic movement as major corridors.

There has been a massive upsurge in total number of registered vehicles in Delhi during 1971-1987 which has witnessed aproximately 5 fold increase (Fig. 1 [5]). The distribution pattern of different categories of vehicles for Delhi clearly depicts that two and three wheelers predominate the scene, constituting approximately 70% of total registered vehicles whereas four wheelers (car, jeeps, etc.) 20%, goods vehicles 7%, and buses 1.5% (Table 6 [5]).

The calculated* total vehicular pollution [5] load for Delhi has clearly shown the increasing trend and it has increased from 424 tonnes/day to 865 tonnes/day during 1980-81 to 1986-87 and the overall increase was approximately 2.2 times. The petrol driven vehicles contributed more than 90% CO and HC while the diesel driven vehicles emitted

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* Calculated using WHO emission factors which have been drived for vehicles of developing countries.

Table 5 : Traffic movement on major corridors

| Major corridor | Total pass. vehicle | Total buses | Total goods vehicle | Total volume |
|---|---|---|---|---|
| 1. Delhi-Faridabad | 21585 | 1936 | 6795 | 30316 |
| | (71.2) | (6.4) | (22.4) | (100.0) |
| 2. Delhi-Gurgaon | 9407 | 1483 | 415 | 14995 |
| | (62.7) | (9.9) | (27.4) | (100.0) |
| 3. Delhi-Bahadurgarh | 3708 | 753 | 2513 | 6974 |
| | (53.2) | (10.8) | (36.0) | (100.0) |
| 4. Delhi-Panipat | 3383 | 1207 | 3712 | 8302 |
| | (40.7) | (14.5) | (45.3) | (100.0) |
| 5. Delhi-Baghpat | 5056 | 474 | 2371 | 7901 |
| | (64.0) | (6.0) | (30.0) | (100.0) |
| 6. Delhi-Ghaziabad | 28714 | 2605 | 11432 | 42751 |
| | (67.2) | (6.1) | (26.7) | (100.0) |
| 7. Delhi-Noida | 16677 | 1623 | 2007 | 20307 |
| | (82.1) | (8.0) | (9.9) | (100.0) |
| 8. Ghaziabad-Meerut | 7047 | 1089 | 3109 | 11245 |
| | (62.7) | (9.8) | (27.5) | (100.0) |
| 9. Ghaziabad-Hapur | 4176 | 789 | 1906 | 6871 |
| | (60.8) | (11.5) | (27.7) | (100.0) |
| 10. Ghaziabad-Bulandshahr | 6110 | 768 | 2141 | 9019 |
| | (67.8) | (8.5) | (23.7) | (100.0) |
| 11. Gurgaon-Behror(NCRB) | 2021 | 613 | 4036 | 6670 |
| | (30.3) | (9.2) | (60.5) | (100.0) |

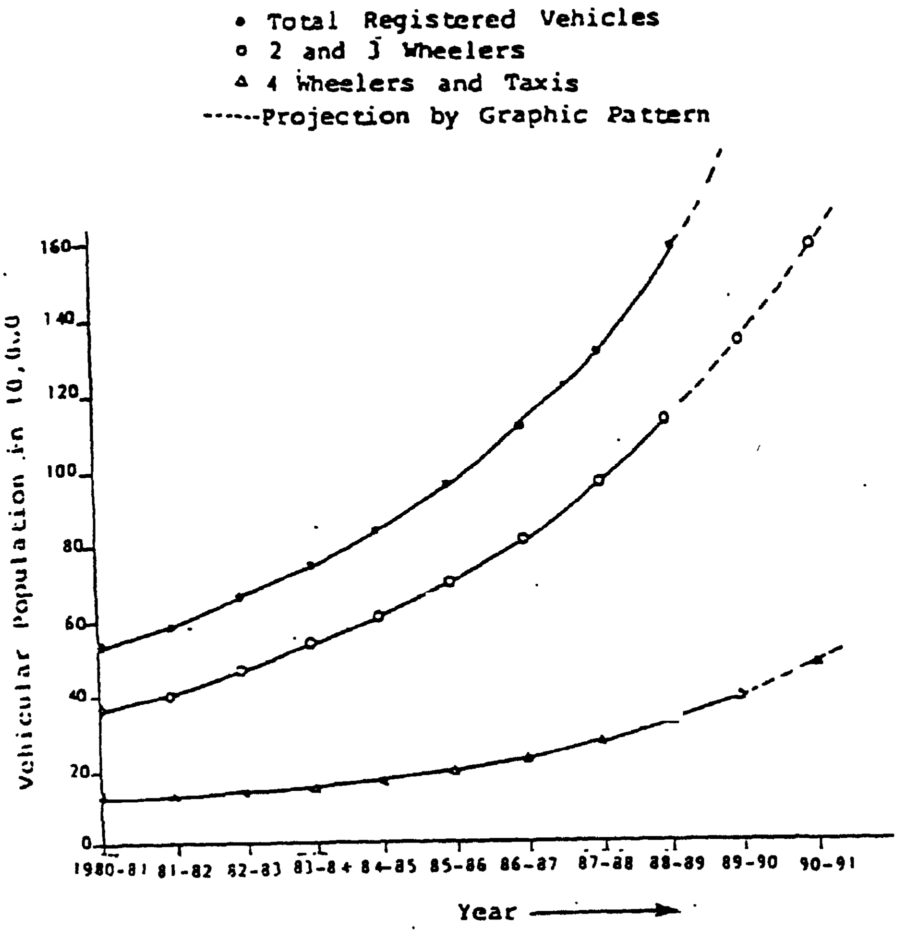

FIG. 1 : GROWTH PATTERN OF DIFFERENT CATEGORIES OF VEHICLES IN DELHI

TABLE 6 DISTRIBUTION OF REGISTERED VEHICLES IN DELHI

| | | | 1971 | 1981 | 1986 |
|---|---|---|---|---|---|
| 1. | Buses | A | 3038 | 8044 | 14037 |
| | | B | 3.36 | 5.21 | 6.10 |
| | | C | 1.70 | 1.5 | 1.46 |
| 2. | Goods Vehicles | A | 13620 | 36599 | 61672 |
| | | B | 4.00 | 6.90 | 7.30 |
| | | C | 7.50 | 6.80 | 6.90 |
| 3. | Cars, Jeeps Taxis, etc. | A | 60292 | 125860 | 188323 |
| | | B | 8.80 | 11.30 | 11.60 |
| | | C | 33.40 | 23.50 | 19.60 |
| 4. | Two wheelers | A | 93253 | 345109 | 665096 |
| | | B | 16.20 | 13.60 | 11.50 |
| | | C | 51.71 | 64.40 | 69.20 |

A = Total number of vehicles (registered)

B = Percentage of total Registered vehicles in India.

C = Percentage of total Registered vehicles in Delhi.

Source: Motor Transport Statistics 1983-84, 1984-85 and Ministry of Surface Transport.

approximately 84% $NO_x$ when compared with total pollution load. Among the petrol driven vehicles two and three wheelers contributed approximately 44% of total CO emitted in 1980-81 which has risen to 54% by 1986-87. While the corresponding figures for hydrocarbons were 75 to 81. The four wheelers emitted approximately 43% total CO discharged and its share has come down to 33% by 1986-87. The corresponding figures for hydrocarbons has also shown the decreasing trend i.e. from 20% to 13.4% (Table 7 [5]).

In actual practice, the pollution load is higher than that of calculated values due to poor maintenance and old aged vehicles. IIT Delhi, during 1984 carried out 8 hourly air quality monitoring at different traffic intersection. The results [5] show that CO concentrations were very high around most of the intersection monitored and the worst effected areas are Delhi Gate (6087.23 μ g/m$^3$). Azadpur (5606.65 μ g/m$^3$), Koria Bridge and Vikas Minar (5446.56 μ g/m$^3$). While the concentrations of $NO_x$ ranged in between 35.7 μ g/m$^3$ (Raja Garden crossing) to 536 μ g/m$^3$ (Radhu Cinema Chowk). The ambient air quality monitoring carried out by Central Board at ITO Booth, shows the increasing concentration of CO during the last two years, ranging in between 4-8 ppm as an average with peak values touching at 25 ppm. The maximum observed impact would be during winter.

## TABLE 7 : VEHICULAR EMISSION INVENTORY OF DELHI 1986-87

| Sl. No. | Category of vehicles | No. of registered vehicles in Delhi | Pollution Load (Tonnes/day) PM | $SO_2$ | $NO_x$ | CO | HC |
|---|---|---|---|---|---|---|---|
| A. | **Petrol Driven** | | | | | | |
| 1. | Cars, Jeeps & Station Wagons | 2,11,774 | 1.49 | 0.36 | 14.47 | 180.95 | 27.1 |
| 2. | Taxis | 8,808 | 0.09 | 0.021 | 0.859 | 10.7 | 1.61 |
| 3. | Two wheelers | 7,70,110 | 3.02 | 0.302 | 1.05 | 256.76 | 151 |
| 4. | Three wheelers | 41,651 | 0.311 | .031 | 0.109 | 33.10 | 15.57 |
| 5. | Three wheelers (Goods) | 3,500 | | | | | |
| B. | **Diesel Driven** | | | | | | |
| 1. | **Buses** | | | | | | |
| | a) Registered in Delhi | 14,766 | 1.4 | 2.8 | 38.9 | 23.5 | 3.9 |
| | b) Entering & Leaving | 1,500 (app.) | | | | | |
| 2. | Goods vehicles | 64,555 | 2.27 | 3.96 | 59 | 39.9 | 8.8 |
| | Grand Toal | 1111664 | 8.58 | 7.47 | 105.388 | 535.9 | 207.98 |

Total vehicular pollution load = 865.318 Tonnes/day

## 4.4 POWER PLANTS

The power generation scenario in the NCR is shown in Table 8 [6].

The main pollutants from power plant (thermal), is SPM. Besides that sizeable amount of $NO_x$ and $SO_x$ are also emitted from thermal power plants. Gaseous discharges from a 210 MW Thermal Power Plant has been calculated and shown in Table 9 [7]. Emissions factors for natural-gas combustion is tabulated in Table 10 [2].

Table 8: Power Generation in the National Capital Region (as on 31.3.1985)

| Name of scheme | Location (Tehsil) | Type | Units x Rated capacity (MW) | Total Installed capacity (MW) | Probable date of commissioning, if not already commissioned |
|---|---|---|---|---|---|
| I. Existing | | | | | |
| 1. Rajghat | Delhi | Thermal | 1 X 14 | 14.0 | |
| 2. I.P. Estate | Delhi | Thermal | 1 X 35 +<br>3 X 62.5 +<br>1 X 60 + | 282.5 | |
| 3. Badarpur | Delhi | Thermal | 3 X 100 +<br>2 X 210 + | 720.0 | |
| 4. Panipat-Stage-1 | Panipat | Thermal | 2 X 110 | 220.0 | |
| 5. Faridabad | Ballabhagarh | Thermal | 1 X 15 +<br>3 X 60 | 195.0 | |
| | | | | 1431.5 | |
| II Under Construction | | | | | |
| 1. Rajghat | Delhi | Thermal | 2 X 67.5 | 135.0 | Unit I – May 88<br>Unit II – Sep. 88 |
| 2. Gas Turbine Scheme near I.P. Station (I.P. Estate) | Delhi | Gas | 6 X 30 | 180.0 | 1st Unit to be commissioned in April 86 and one unit per month thereafter |
| 3. Panipat Units 3,4,5 (Stages II & III) | Panipat | Thermal | 2 X 110<br>1 X 210 | 430.0 | Unit 3 – Oct. 85<br>Unit 4 – Aug. 85<br>Unit 5 – Dec. 87 |
| 4. Kokroi | Sonepat | Hydel | 3 X 0.1 | 0.3 | 1986-87 |
| 5. Narora | Anupshahr | Atomic | 2 X 235 | 470.0 | Unit I – Dec. 87<br>Unit II – Dec. 88 |
| | | | | 1215.3 | |
| III. Proposed in the Seventh Plan | | | | | |
| 1. Muradnagar | Ghaziabad | Thermal | 4 X 210 | 840.0 | Unit I – 1992-93<br>Unit II – 1993-94<br>Units III & IV – 1994-95 |
| | | | | 840.0 | |
| | Grand Total: | | 3486.8 | | |

Table 9: Gaseous Discharges form a 210 MW Thermal Power Station

| Sl. No. | Gaseous Discharges | Emission/year | Concentration |
|---|---|---|---|
| 1. | Flyash | 0.228 million Tonnes | 78 g/cu.m |
| 2. | Nitrogen Oxides | 10,679 Tonnes | 3.5 g/cu.m |
| 3. | Carbon Monoxide | 356 Tonnes | 93 ppm |
| 4. | Sulphur Oxides | 3,584 Tonnes | 1.25 g/cu.m |
| 5. | Hydrocarbons | 107 Tonnes | 15 ppm |
| 6. | Carbon Dioxide | 1,033 Million Tonnes | 20% |

Table 10: Emission Factors for NG Combustion for Power Plant

| Sl. No. | Pollutant | Kg/10$^6$m$^3$) |
|---|---|---|
| 1. | Particulate | 80-240 |
| 2. | Sulphur Oxides | 9.6 |
| 3. | Nitrogen Oxides | 11,200 |
| 4. | Hydrocarbons | 16 |
| 5. | Carbon Monoxide | 272 |

## 5. WORK PLAN

| Activity | Time Frame<br>Start Date | <br>End Date |
|---|---|---|
| 1. Methodology Paper | May '89 | August '89 |
| 2. Collection of Data | September '89 | March '90 |
| 3. Model Framework and Program Development | September '89 | March '90 |
| 4. Interim Report | April '90 | May '90 |
| 5. Model Verification and Scenario Generation | June '90 | February '90 |
| 6. Report Preparation | March '91 | May '91 |

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